

## My patient is injured: identifying foreign bodies with ultrasound

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### Abstract

Patients commonly present to the emergency department with a suspected retained foreign body, following penetrating injury. While plain radiography is often the first line in identifying radio-opaque foreign bodies, radiolucent foreign bodies such as wood and plastic can easily be missed. Furthermore, real-time visualization of such a foreign body can assist in its removal. This article evaluates the use of point-of-care ultrasound by emergency physicians in the identification and removal of soft-tissue foreign bodies along with describing the appropriate technique and highlighting the potential pitfalls. An illustrated case example is presented that highlights the benefits of point-of-care ultrasound foreign body detection and guided removal.

**Keywords:** Interventional ultrasound, education, foreign body, point-of-care ultrasound

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### Clinical question

In patients presenting to the emergency department following a penetrating injury, can point-of-care ultrasound (PoCUS) be used by emergency physicians to identify and guide the removal of foreign bodies?

### Introduction

Penetrating injury, including both incisional and puncture wounds, is a common presentation to the emergency department. The risk of retained foreign body is usually determined by the history of the injury, e.g. splinter puncture wound with ongoing local tenderness or multiple incisions to the hand following a punch through a glass window. Identification of retained foreign bodies is an important step in the primary evaluation of such patients. A systematic physical examination of the puncture site along with conventional radiographic investigation is routine for initial assessment. Radio-opaque foreign bodies are identified on X-ray, although precise depth and location can be difficult to determine and removal is not always straightforward. Non-radiopaque foreign bodies such as wooden splinters or thorns are missed in up to 38% of patients at initial investigation in emergency departments.<sup>1</sup> Failure to diagnose these injuries can result in complications such as tendon sheath infection and abscess formation. Prolonged foreign body localization attempts can also lead to

iatrogenic complications such as unnecessary large skin incision and neurovascular injury, which can increase the risk of infection and blood loss.

Ultrasonography has demonstrated high sensitivity and specificity in identifying and localizing both radiopaque and, more importantly, radiolucent foreign bodies, including those missed by plain radiography.<sup>2,3</sup> A good understanding of the sonographic characteristics of the various kinds of foreign bodies is important when correlating with the patient history, and can improve accuracy.

Point-of-care ultrasound (PoCUS)-guided removal of foreign bodies provides added benefit that could lead to it becoming the preferred imaging modality when managing patients with potential foreign bodies in the emergency department.

### Case example

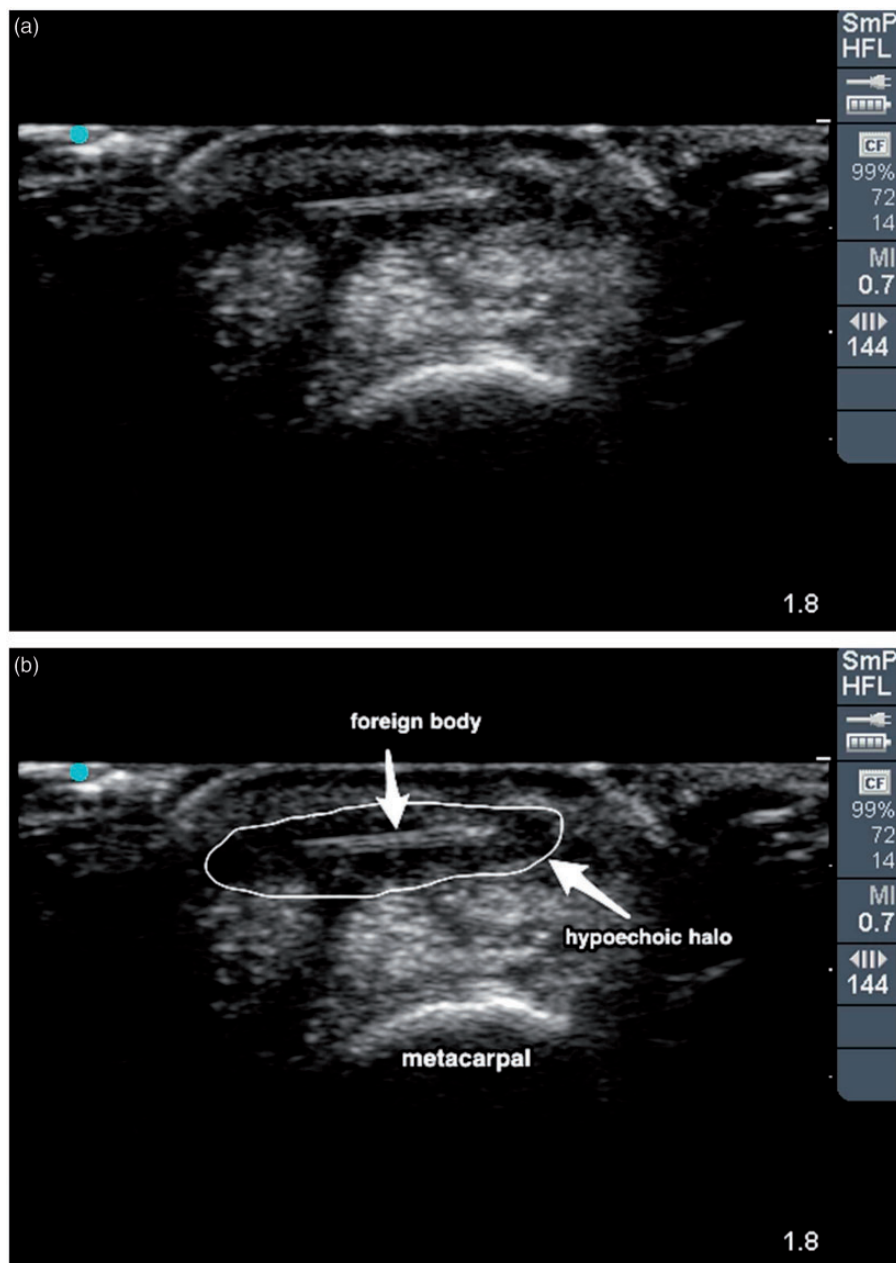
A 65-year-old lady presents with pain and redness over the base of her left thumb. She had been working in her son's garden 1 week earlier and had sustained a puncture wound. She attended her local minor injuries unit, where she was examined and plain radiographs were obtained. She was advised that no foreign body was evident, but to attend the emergency department if her symptoms did not improve.

She attended the emergency department 1 week later with persistent symptoms of pain and swelling. When

examined by the emergency physician, erythema was noted and there was swelling of the thenar eminence. PoCUS was performed using a SonoSite MicroMaxx (FUJIFILM SonoSite Inc., Bothell, US) with HFL linear transducer (13-6 MHz). A 0.8 cm hyperechoic foreign body was identified 0.4 cm deep to the surface. The foreign body was surrounded by a hypoechoic halo consistent with a reactive inflammatory process (see Figure 1). Under ultrasound guidance, 1% lidocaine was injected around the foreign body and left in-situ over the most superficial end. A small incision was made along the needle and the wooden splinter directly visualized. Fine splinter forceps

were used to remove the splinter, which was then measured at 0.8 cm.

This case highlights the limitations of plain radiography in the assessment of radiolucent foreign bodies. Whilst it can rule out retained radiopaque material, a negative plain radiograph does not rule out all foreign bodies. A common approach to managing these patients often involves a routine follow-up diagnostic ultrasound in the radiology department. This may involve the patient returning to the hospital on a later date and can result in some inconvenience. This case describes an evolving practice utilised by some emergency departments, where the use of PoCUS



**Figure 1** Transverse view of the thenar eminence of the left hand (Sonosite 13 MHz linear transducer) (a). A duplicate image is labeled (b). A hyperechoic linear structure can be identified in the superficial tissue. A hypoechoic halo surrounds the foreign body, consistent with a delayed inflammatory response and correlating with the 1-week retention history

has resulted in early detection and removal of radiolucent foreign bodies and reducing the need for recurrent patient visits to hospital.

### How accurate is ultrasound for detecting foreign bodies?

In most hospitals, diagnostic ultrasound is the modality of choice for identifying radiolucent foreign bodies. Its accuracy in the hands of experienced sonographers is supported in the medical literature. Sensitivities of up to 94–98% for ultrasound detection of both radiolucent and radiopaque foreign bodies have been reported.<sup>2,3</sup>

In addition to its high diagnostic accuracy, ultrasound has the benefit of real-time visualisation, which can significantly improve foreign body removal and reduce complications of the procedure.<sup>4</sup>

### How accurate is emergency physician-performed PoCUS for detecting foreign bodies?

Given the accuracy of diagnostic ultrasound in detecting foreign bodies, does the evidence support the use of PoCUS by emergency physicians?

A study by Nienaber et al.<sup>5</sup> evaluated the accuracy of six emergency physicians in detecting wood, glass, plastic, gravel and metals in experimental models of soft tissue foreign bodies. Out of 30 foreign bodies, 29 were correctly identified, and the study yielded sensitivity, specificity, positive predictive value and negative predictive value of 96.7%, 70%, 76.3% and 95.5%, respectively.

Another study compared the accuracy of three senior emergency physician residents with two trained sonographers and one radiologist in detecting radiolucent foreign bodies in chicken thighs using ultrasound. The emergency physicians had no prior ultrasound experience but attended a two-day (16 hours) PoCUS course. All participants received a 1-hour foreign body detection training session. The accuracy (95% CI) of the radiologist was 83% (75, 90); of the ultrasound technologists was 85% (80, 90) and of the emergency physicians was 80% (76, 85). There was no statistically significant difference in accuracy between the three types of personnel.<sup>6</sup>

Atkinson et al.<sup>7</sup> compared the accuracy of PoCUS in detecting wood, metal and plastic foreign bodies in an experimental model by emergency physicians and emergency nurse practitioners following a short training workshop. Sensitivities of between 83.3 and 100% were demonstrated.

### How accurate are other imaging modalities?

Nearly all foreign bodies are composed of glass, wood or metal. All metals except for aluminum can be visualized with plain radiography. In addition, nearly all glass fragments larger than 2mm can be seen regardless of pigment or lead content. Most types of wood are either completely radiolucent or produce subtle nonspecific

findings. Other common sources of foreign bodies include plastic, cactus and sea urchin spines, thorns and fish-bones, each with a varying degree of radiopacity. In a retrospective review of foreign bodies of the hand, 38% of foreign bodies were missed on initial examination. Of the 26 false-negative plain radiographs, 23 were composed of wood.<sup>8</sup>

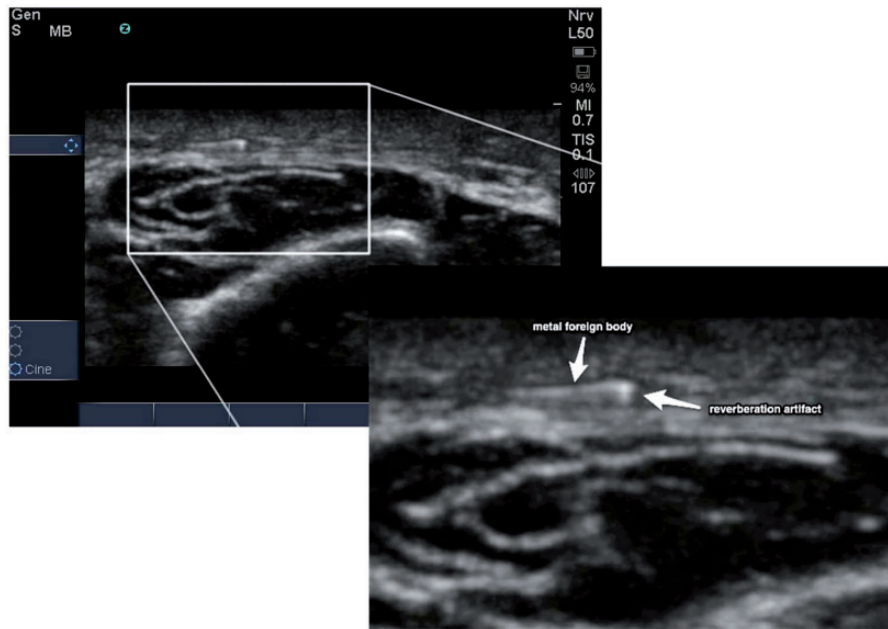
CT and MR have shown greater sensitivity than plain radiographs in detecting foreign bodies; however, these are often more difficult to obtain at the time of presentation to the emergency department and are more costly. CT may not be as sensitive as ultrasound for radiolucent foreign bodies. A recent study showed that CT correctly identified 70% of all foreign bodies, compared with 90% identified by ultrasound.<sup>8</sup>

Whilst fluoroscopy and CT can be used to guide localisation and removal of foreign bodies, their use at the bedside is limited and also involves exposure to potentially harmful ionizing radiation.

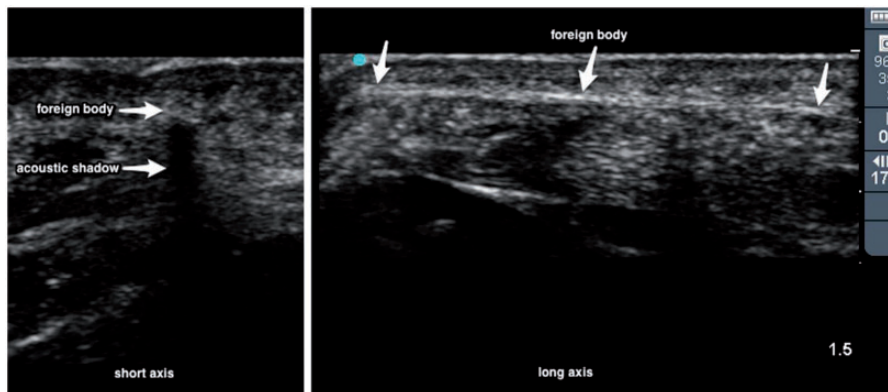
### Ultrasound characteristics of foreign bodies

All foreign bodies are hyperechoic compared to soft tissue, and they interrupt the normal homogenous echotexture of the adjacent tissue. Different materials have characteristic echo patterns, which can assist in the identification of a foreign body. Metal is brightly hyperechoic with a comet tail or reverberation artifact that is visible deep to and in close proximity with the foreign body (see Figure 2). Glass is also brightly hyperechoic, but has a more scattered comet tail artifact. Wood and plastic are generally hyperechoic with acoustic shadowing of variable depth and density (see Figure 3). Wood and other organic material foreign bodies become more isoechoic with surrounding tissue with increased duration in-situ. Cactus spines generate a similar appearance to wood. Sand and pebbles produce a strong acoustic shadow not unlike a gallstone.<sup>8,9</sup> An inflammatory process usually develops within 24 hours of the presence of a retained foreign body, which appears as a hypoechoic halo around the foreign body (see Figure 4). This can also help with the identification of a retained foreign body. This inflammatory process is more marked and accelerated with organic material e.g. wood or contaminated metal.

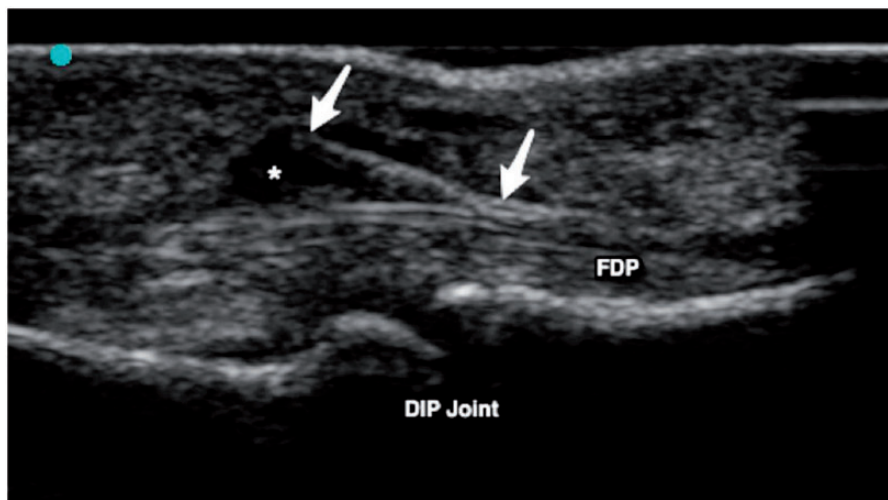
Ultrasound can also be useful for identifying delayed complications of a foreign body, such as infection. Infection can result in the development of an abscess, which will appear as an anechoic collection on ultrasound. Certain gas-forming organisms can lead to small gas bubbles within the tissues or abscess. While air can also be introduced into the soft tissue along with the foreign body at the time of penetration, this generally resolves rapidly. Gas secondary to bacterial infection typically presents within a hypoechoic halo surrounding the foreign body. Tiny gas bubbles are hyperechoic and do not generate a characteristic comet tail due to their size. Detection is often based on their movement upon applying pressure with the ultrasound probe.<sup>10</sup>



**Figure 2** Longitudinal view of the sole of the foot (Sonosite 13 MHz linear transducer) (a). The enlargement (b) demonstrates a small hyperechoic linear structure with a closely related reverberation artifact just deep to the structure



**Figure 3** Short axis (a) and long axis (b) views of a foreign body in the palm of the hand (Sonosite 13 MHz linear transducer). A hyperechoic linear structure is seen in the superficial tissues. An acoustic shadow (labeled) is more pronounced in the short axis view



**Figure 4** Longitudinal view of a glass foreign body in the volar aspect of the index finger (Sonosite 13 MHz linear transducer). A hyperechoic linear structure lies obliquely within the superficial tissues. This is a glass splinter (arrows). A hypoechoic halo (\*) of inflammatory fluid can be seen extending around the splinter and into flexor tendon sheath. FDP: flexor digitorum profundus; DIP: distal interphalangeal joint



## Technique – localisation

A high-frequency transducer, which generates short wavelength ultrasound and therefore better axial resolution, will allow for detection of the smallest foreign bodies. While high frequency also results in a lower penetration, this has little implication in this situation, as most foreign bodies are relatively superficial.<sup>11</sup>

For very superficial foreign bodies or where the body part has an irregular contour, image quality can be improved using a spacer or a gel pad. In these circumstances a water bath can also be used, which has the additional advantage of being non-contact and therefore avoiding the discomfort associated with transducer contact with the injured part (see Figures 5 and 6).

To best localize the foreign body, the entire injured part should be scanned in both transverse and longitudinal planes. Starting from the point of penetration, the transducer is moved radially in both planes. The trajectory of the foreign body may be anticipated by the history of the injury and a general search area may be identified by point of maximal tenderness. However, for the majority of small foreign bodies the trajectory is unreliable and the entire area is tender. In addition, not all penetrating injuries result in retained foreign body. A splinter wound to a hand will appear the same to external examination whether a fragment of splinter is retained or not. Therefore in order to be able to 'rule-out' the presence of foreign body after a penetrating injury, a full survey of the affected body part is required. As with most PoCUS techniques 'ruling-in' a foreign body is much easier than 'ruling-out' a foreign body.

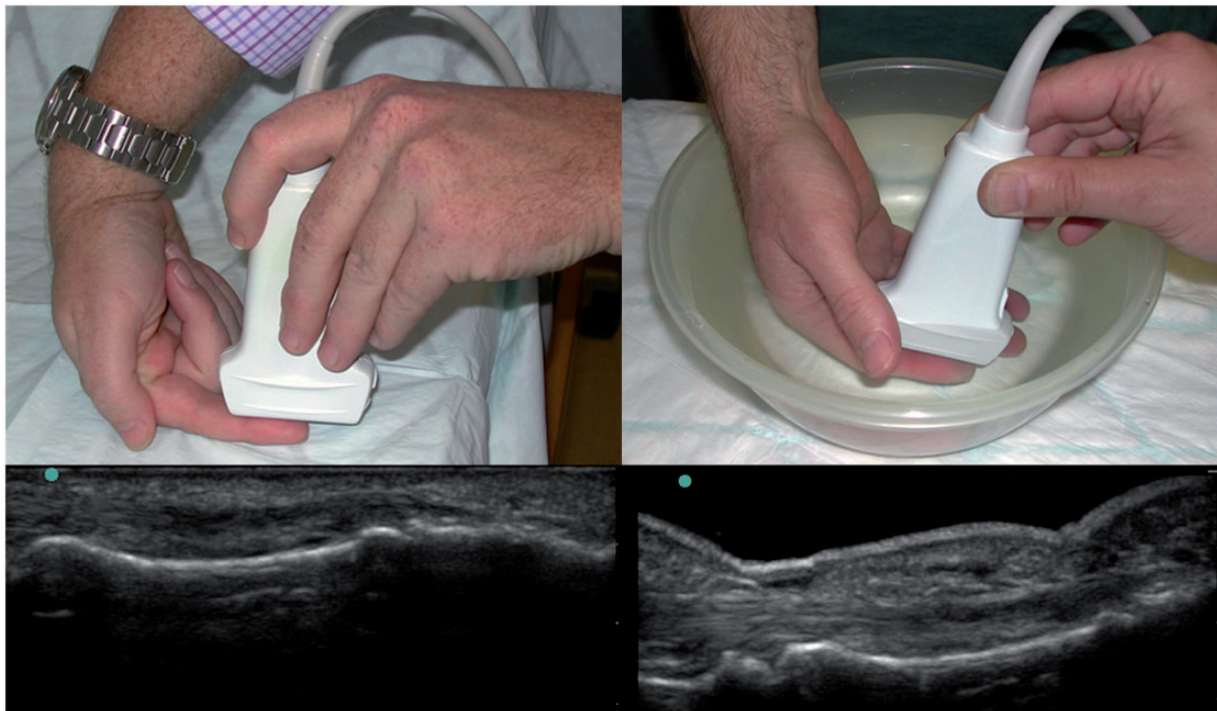
False positives can occur; these include sesamoid bones, hyperechoic muscle fibres and tendons. The majority of foreign bodies will be linear in shape. Once located, they should be visualized in both long and short axis. If it is unclear whether a foreign body is in fact present, comparison with the contralateral side at the same location is often helpful.

Once a foreign body is identified, its approximate length and distance from the skin should be measured. Nearby structures such as vessels, nerves, tendons and joint spaces should also be localized relative to the location of the foreign body. The point where the foreign body is in closest proximity to the skin along the plane of its long axis should be identified and marked on the patient's skin. This will reduce tissue damage and make retrieval simpler.

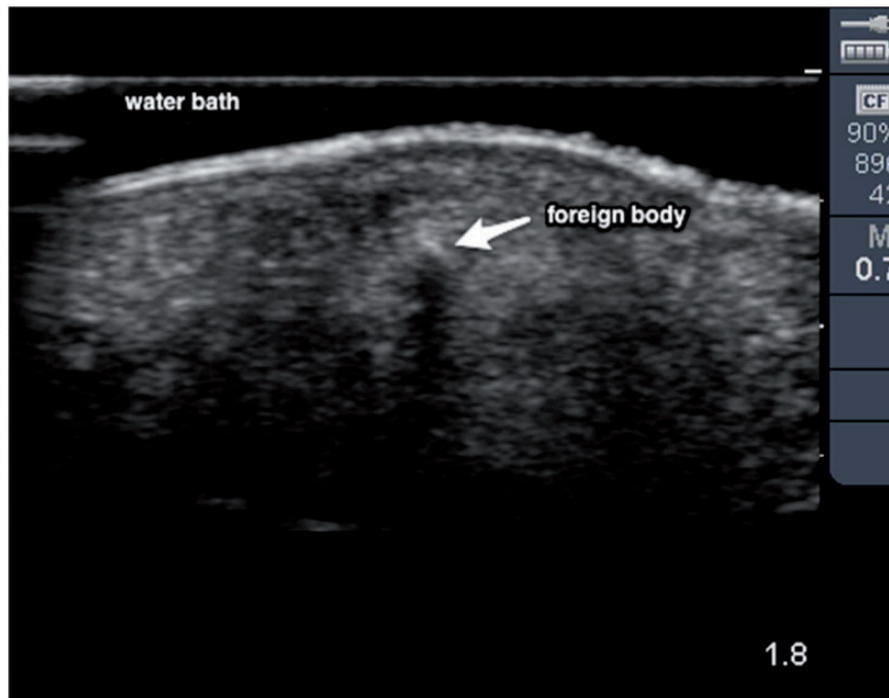
## Technique – ultrasound guided extraction

### Needle localization technique

Under ultrasound guidance, an 18-g needle is inserted through the skin onto the foreign body. Local anaesthetic is infiltrated around the foreign body and along a track back to the skin surface and around the proposed incision site. The needle is once again guided back onto the foreign body and left in situ. Once the anaesthetic has taken effect, a scalpel is used to make a careful incision down to the end of the locating needle. Blunt dissection should be used when in close proximation to neurovascular structures and tendons. Where possible, a tourniquet can be used to minimize



**Figure 5** Comparison of image quality between standard (a) and water bath (b) techniques when scanning irregular small parts. Longitudinal views of volar surface of index finger (a common site for foreign body injury) are presented. A Sonosite 13 MHz linear transducer is used (Sonosite have confirmed that this technique is compatible with the safety specifications of their transducer)



**Figure 6** Transverse view of a very small glass foreign body in the hypothenar eminence of the palm (Sonosite 13 MHz linear transducer). The foreign body is labeled and a characteristic acoustic shadow can be seen extending deeply

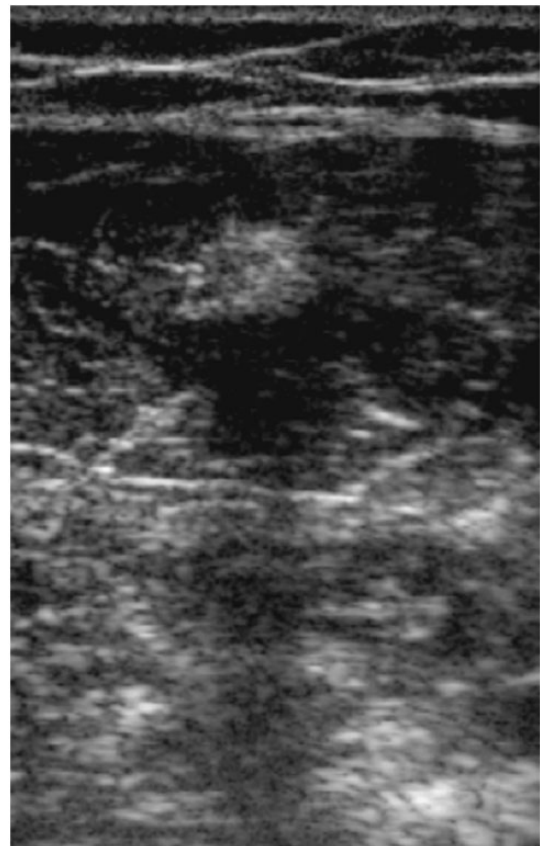
bleeding from obscuring visibility in the incised wound. Once visualized, the foreign body can then be removed with fine forceps or splinter forceps.<sup>12</sup>

### Real-time ultrasound-guided extraction

The skin should then be disinfected using sterile technique. The ultrasound probe should also be isolated using a sterile glove or sheath. Under ultrasound guidance, an 18-g needle is inserted through the skin onto the foreign body. Local anaesthetic is infiltrated around the foreign body and along a track back to the skin surface and around the proposed incision site. A 0.5- to 1-cm incision should be made in the plane of the foreign body's long axis orientation, with a sterile scalpel. Ensure that the incision is large enough to accommodate the entire foreign body. While under real-time visualisation with ultrasound, fine splinter forceps should be introduced into the incision site, while bluntly dissecting a path to the tip of the foreign body. The foreign body should then be extracted through the path of entry, with a firm grip, while under continual direct visualization. The ultrasound examination should be performed once again to ensure that the entire foreign body has been removed, and that there are no remnants. The incision site can then be irrigated and closed with sutures.

### Limitations and pitfalls

Various normal and pathological structures can also present as foreign bodies, resulting in false positives. The physician must be able to differentiate a foreign body from sesamoid bones, scar tissue, pus, hematoma and traumatic air, all of which can cause a disruption of the homogenous soft tissue



**Figure 7** Transverse view of the anterior thigh (Sonosite 13 MHz linear transducer). An area of discrete hyperechogenicity is seen with an acoustic shadow extending deeply. This is an area of heterotopic calcification secondary to recurrent thigh haematoma. Physicians using PoCUS should be aware of both normal and pathological structures that can mimic foreign body

echo-texture (see Figure 7). While a hypoechoic halo typically represents an inflammatory reaction, or granulation tissue around a foreign body, the presence of such a halo may result in false positive detection of a foreign body even after the foreign body has been removed. The presence of air bubbles due to introduction during penetration, or due to abscess formation, can often limit visualization of the foreign body. Furthermore, the soft tissues in smaller more complex parts of the body, such as the hands and feet, contain various structures and soft-tissue plains. The disruption of the underlying echo-texture is therefore often a less useful indicator of the presence of a foreign body.

Emergency physicians should be aware that while their accuracy will improve with experience, a negative scan in the context of a penetrating injury history does not rule out a retained foreign body. In those patients with negative scans and examination findings consistent with retained foreign body, either delayed follow-up assessment or utilization of a diagnostic imaging department may be required.

In addition, emergency physicians should be aware that the quality of equipment will play an important role in their accuracy and should not rely on the findings generated by low-quality platforms or low-frequency transducers.

## Conclusion

Retained foreign body secondary to penetrating injury is a common presentation to the emergency department. Clinical examination and plain radiography can miss a large proportion of these foreign bodies. Given a history of penetrating trauma and an examination that suggest possible retained foreign body, PoCUS can be a cost-effective, timely tool for identification and guiding the removal of foreign bodies of various compositions.

In the last 10 years many emergency physicians have received training in PoCUS and have access to increasingly high-quality ultrasound equipment. A growing number of studies have shown comparable sensitivities in identifying foreign bodies in experimental models between emergency physicians and experienced sonographers. While these results should be interpreted with some caution and their extrapolation to general emergency medicine clinical practice warrants further investigation, it is clear from the literature that this is a skill that can be learned by emergency physicians. As with all PoCUS skills, emergency physicians can develop expertise through ongoing training and

experience and should ensure quality practice by regular audit and research.

## DECLARATIONS

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**Guarantor:** PA.

**Contributorship:** DL and AJ performed the review of the literature and writing of the manuscript. PA and RJ conceived the idea, reviewed the literature and reviewed the manuscript.

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